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AIRCRAFT SEPARATION ASSURANCE TECHNICAL DEVELOPMENTS.(U)
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FEDERAL AVIATION ADMINISTRATION

AIRCRAFT SEPARATION ASSURANCE TECHNICAL DEVELOPMENTS

Submitted to the Subcommittee
on Transportation, Aviation,
and Communications, Committee on
Science and Technology
House of Representatives

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16. Abstract

It is the purpose of this paper to provide background on the portion of the FAA plan that relates to the technical systems needed for aircraft separation assurance and future avionics requirements. This discusssion will deal with the technology developments and the rationale for the actions taken and proposed.

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FAA AIRCRAFT SEPARATION ASSURANCE TECHNICAL DEVELOPMENTS

On December 27, 1978, the Secretary of Transportation and the Federal Aviation Administrator announced a comprehensive program intended to further improve the safety of the flying public. In that "Plan for Enhanced Safety of Flight Operations in the National Airspace System," the Administrator announced a series of actions intended to provide a high level of protection for the flying public while retaining a large degree of freedom of airspace usage consistent with this safety goal. The plan describes a series of programs to be implemented and other programs that are planned and being proposed. It is clear that no single action will ensure the desired level of safety as the density of traffic rises, but that a series of integrated services is needed to achieve and maintain the high level of safety to which the American public has become accustomed.

It is the purpose of this paper to provide background on the portion of the FAA plan that relates to the technical systems needed for aircraft separation assurance and future avionics requirements. This discussion will deal with the technology developments and the rationale for the actions taken and proposed.

Summary of the Plan

The Administrator's plan calls for increasing radar services at 80 air carrier airports, establishing mandatory terminal control areas at 44 additional locations and putting most of the busiest air routes above 10,000 feet under direct air traffic control.

In addition to these measures, the FAA will propose regulations requiring wider use of altitude reporting Air Traffic Control Radar Beacon System (ATCRBS) transponders by all aircraft operators and installation of collision avoidance systems in most airliners as soon as this equipment becomes available.

FAA also will expedite ongoing research and development efforts in the air traffic control field and continue with the installation of additional safety facilities at airports. For example, the FAA will install 24 instrument landing systems (ILS) at general aviation (non-airline) airports in large metropolitan areas to accommodate practice instrument approaches. It also will install equipment at eight airport control towers that will permit direct radar readout of such vital flight information as aircraft identity and altitude.

As a consequence of the research and development on aircraft separation assurance, FAA plans to issue an advance notice of proposed rule making in March 1979, soliciting industry and public comments on such additional regulations as:

- o Requiring altitude-reporting Beacon transponders for all aircraft operations in Terminal Control Areas and Terminal Radar Service Areas (TCA/TRSA) by July 1981. In addition, all transponders installed in aircraft after July 1982 will be required to be a new version known as the Discrete Address Beacon System (DABS) which among other evolutionary improvements provides a means for automatic "data link" communications for use with a ground-based collision avoidance system.

- o Requiring all airliners and air taxi aircraft to carry an Active Beacon Collision Avoidance System (BCAS) by January 1985. This device triggers transponder replies from other aircraft, evaluates the position and altitude information and advises the pilot when a potential problem exists and what evasive action is necessary, if any.

Objectives of the Plan

The National Airspace System consists of two operational modes:

- o A system of controlled airspace, in which separation is provided by procedural, radar or visual means along defined routes and airways for aircraft in contact with the air traffic control services and operating under Instrument or Controlled Visual Flight Rules. The plan expands the airspace in which control and separation services are provided and made obligatory.

- o A system of uncontrolled airspace, which operates under Visual Flight Rules (VFR), is used heavily by general aviation, and relies primarily on procedures and see-and-avoid as its means of collision avoidance.

The two modes have distinctly different mid-air collision problems. The large majority of collisions have occurred outside of control in VFR airspace, most frequently between general aviation aircraft with one or two occupants, near uncontrolled airports. However, a collision risk exists in controlled airspace as well, as evidenced by FAA system error reports, pilot near-midair collision reports, and reports through the Aviation Safety Reporting System. That risk, though historically small, rises as traffic density rises. The features of the plan are

intended primarily to reduce the collision risks within the controlled system.

The plan takes a dual approach to collision avoidance or aircraft separation assurance. This approach provides for a ground-based primary system, backed up by an airborne system. The two work together to provide maximum protection to the greatest number of people who fly.

This paper describes the Automatic Traffic Advisory and Resolution Service and the Discrete Address Beacon System that makes it possible, the development of airborne collision avoidance systems, and the relationships among them. It also touches briefly on an FAA development concept called the Automated Terminal Service which may bring a level of additional collision protection to uncontrolled airports where historically the largest numbers of collisions have occurred.

Background Facts

Eight years of National Transportation Safety Board collision statistics (Figure 1) show that collisions occur most frequently outside the control system or at the boundary between controlled and uncontrolled airspace. Over the eight-year period 1970-1977 there were 187 collisions between two uncontrolled VFR aircraft, with 228 fatalities. In addition, there were 13 collisions involving one controlled and one uncontrolled aircraft, with 105 fatalities. While the 1978 San Diego collision is not represented in these data, it remains true that there are relatively few collisions involving air carrier aircraft, and most air carrier fatalities have occurred under circumstances in which a controlled air carrier aircraft encountered an uncontrolled military or general aviation aircraft.

However, even without the San Diego case, this record is not satisfying, in that other measures of safety indicate that risks of potential collisions continue to exist in the controlled system. This is shown by the high air carrier involvement in incident reports shown in the statistics listed in the lower portion of Figure 1.

The FAA has for several years collected system error reports from controllers and near-midair collision reports from pilots. These reports are investigated and verified. Figure 1 shows a compilation of reports in each category. These data show a high involvement of air carriers and a large concentration of incidents within the terminal area.

A new and additional concern has been raised by the Aviation Safety Reporting System administered by NASA. Among the reports received, 228 reports in the first year and half of operation concerned altitude deviations. These were all reported out of the controlled system, and consisted of aircraft which for one reason or another flew through their altitude clearances. These reports are over 50% air carrier, and one in ten led to a loss of vertical separation. While there are limitations in the NASA reporting system, in that the reports are from single individuals and not verified by investigation, this represents another dimension of mid-air collision risk within the controlled system.

In sum, the majority of risk of collision fatalities for air carriers is concentrated in the terminal area part of the controlled system where traffic densities are high. Because of the traffic mix, the air carrier risk is highest at the fringes of the terminal control system. In contrast, most of the general aviation collisions occur at the 12,500 small airports where there are no control facilities. These two areas are important facets of the collision problems addressed by FAA's Aircraft Separation Assurance Program.

Collision Avoidance Systems Development

FAA's development programs for airborne collision avoidance systems are intended to produce systems that work under all weather and traffic conditions. They are intended to electronically "see" all aircraft of concern, to use computers to automatically detect possible threats, and to display to the pilot (and the controller, in some approaches) an alert, along with a recommended maneuver command to avoid a collision. They are intended to operate integrally with the ATC system in controlled airspace, and in some designs to provide a measure of protection to equipped aircraft in uncontrolled airspace as well.

To illustrate this concept, consider that the system functions by setting up an electronic shield around the protected aircraft (Figure 2). Any other aircraft that is projected to pass through this shield within a pre-determined time will cause an alarm accompanied by a recommended maneuver. This pre-set time, known as the warning time, is typically 30 to 40 seconds.

The size and shape of the electronic shield is critical, since a shield that is too large or improperly shaped will cause too many false or unwanted alarms, while one which is too small (or improperly shaped) will not provide sufficient protection. Further, it is difficult to control the size and shape of the electronic shield, since it is determined by factors such as the

ACTUAL COLLISIONS
1970-1977 (NTSB)

	BOTH UNDER CONTROL	CONTROLLED / UNCONTROLLED	BOTH UNCONTROLLED
AN AIR CARRIER INVOLVED	1 / 2	3 / 52	1 / 14
ONLY GENERAL AVIATION INVOLVED	30 / 49	10 / 53	186 / 214

COLLISIONS / FATALITIES

SYSTEM ERROR REPORTS 1977
(FAA CONTROLLER REPORTS)

	ENROUTE	TERMINAL	TOTAL
TOTAL	225	296	521
AT LEAST ONE AIR CARRIER INVOLVED	69%	55%	61%

NEAR MID-AIR COLLISION REPORTS
1975 (FAA IMMUNITY REPORTS)

	ENROUTE	TERMINAL	AIRPORT
TOTAL	79	99	49
AT LEAST ONE AIR CARRIER INVOLVED	25%	36%	24%

ALTITUDE DEVIATION REPORTS
4 / 76 — 10 / 77
(NASA IMMUNITY REPORTS)

TOTAL	SYSTEM ERROR	NEAR MID-AIR
228	16	7

FIGURE 1
MEASURES OF MIDAIR COLLISION RISK

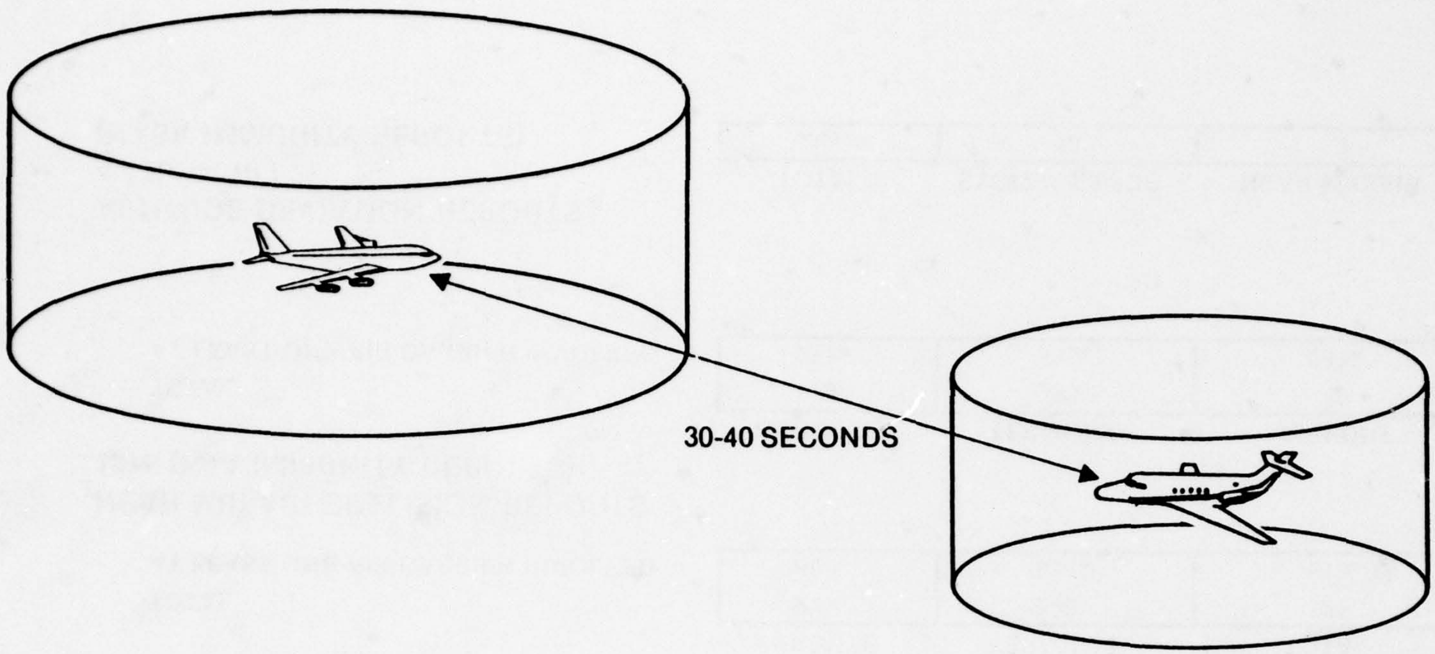


FIGURE 2
BASIC COLLISION AVOIDANCE SYSTEMS CONCEPT

ability to precisely measure the position of another aircraft, the response time of the aircraft involved, the pilot response time, the relative closure speeds, the ATC separation standards in effect at the time, terrain and obstacle avoidance, airport configuration, and the like.

The word "projected" was used to describe the path of the other aircraft of concern. Not all collision avoidance concepts have knowledge of pilot intent, and airborne collision avoidance systems never do. If a pilot intends to change flight path in the next 30 to 40 seconds, but at the moment appears to be on a course that would pierce the protected volume, the system will alarm. This is troublesome in the denser terminal areas where turning aircraft are the rule rather than the exception, and is an additional source of false or unwanted alarms.

Third, false alarms may be unsafe. If a pilot executes a maneuver based on a false alarm, it is necessary to assure that this does not place him suddenly in conflict with another aircraft operating on a perfectly safe course.

Finally, collision avoidance systems differ radically in their ability to establish these electronic screens. Some devices can provide only one or two shapes of screens, while others can continually vary their protective shields as different situations or airspace regions are encountered. The FAA and various equipment manufacturers have been experimenting with a number of collision avoidance system concepts and designs since the late 1950's. The earliest of these were a series of Airborne Collision Avoidance Systems (ACAS), whose history is described in Appendix A. As discussed there, a detailed evaluation of all contending ACAS concepts was completed in 1975, with the conclusion that none could form the basis for system-wide collision protection either in uncontrolled or in high density controlled airspace.

Following this evaluation, and faced by what some felt were insurmountable technological limits, the FAA held a series of public meetings on the collision avoidance question in the period September 1976 through February 1977. These conferences were widely attended by all segments of the aviation and user community. The objective was to review the results of the tests, and to consider various new technologies under parallel development by FAA and DOD that held promise of eliminating many of the shortcomings of the ACAS systems.

As a result of these and other activities, a comprehensive, multi-faceted approach to the collision avoidance problem was

formulated, blending together requirements from the pilot and user community as well as the new technologies under development at the time.

This approach, which FAA calls the Aircraft Separation Assurance Program, forms the basis for the current development efforts.

Cornerstones of the Aircraft Separation Assurance Effort

The following are the cornerstones of the aircraft separation assurance philosophy as it relates to the technical systems development:

- First, even using the latest technology, FAA does not believe it is possible to develop a single Collision Avoidance System that will meet the need in all environments (controlled vs. uncontrolled, high vs. low density). A mix of collision avoidance devices will be required. Independent but coordinated airborne and ground-based solutions to this problem are needed.

- Second, providing high quality collision avoidance service in the denser terminal areas requires that the electronic protective screen discussed earlier be tailored on a site-by-site basis to account for differences in operational procedures, separation standards, obstructions, runway configuration, etc. To be practical, this requires the use of ground-based collision avoidance service tailored to the individual high density airport.

- Third, the need to achieve earliest possible protection for the largest number of aircraft and passengers, requires that users who equip can receive protection from other aircraft which are equipped only with altitude-reporting transponders.

- Fourth, the capability to incorporate a system to provide the pilot with a display of surrounding traffic as well as a maneuver advisory is a highly desirable potential future capability of any anti-collision system.

- Fifth, it is essential to allow for evolution of the system in a manner compatible with future ATC system evolution.

FAA's program is designed to satisfy these fundamental requirements.

FAA is pursuing several separate but coordinated technical developments as a part of the separation assurance effort. It should be stressed that this effort is possible only because of the recent advent of large scale microprocessing technology; technology that did not exist even a few years ago. The major elements of this program are: the Automatic Traffic Advisory and Resolution Service for high density controlled airspace and the Discrete Address Beacon System that supports this service; an active Beacon Collision Avoidance Systems for lower density controlled airspace and some uncontrolled airspace areas as well; a full-capability BCAS development applicable to all airspace; En Route Conflict Alert and Resolution, and Terminal Conflict Alert services; and the development of the concept of an Automated Terminal Service.

Conflict Alert/Conflict Resolution

Conflict Alert, the initial phase of the aircraft separation assurance program, is already operational in most of the National Airspace System. In en route airspace Conflict Alert warns controllers of potential separation minima violations two minutes before they occur. Altitude clearances can be manually inserted into the computer by the controller, which serves to inhibit the generation of a number of false alarms. This system is currently implemented above FL230 in all centers, and in well over half of the low-altitude sectors. The system is also usable on primary radar targets with manual insertion of altitude and manual track initiation.

In the terminal area, Conflict Alert warns controllers of potential separation minima violations some 40 seconds in advance. The logic currently uses 1.2-mile horizontal and 400-foot vertical separation minima criteria. The system is currently implemented in all of the ARTS III terminals except the dual beacon sites, which are scheduled for implementation this year.

Although the system warns of impending violations of separation minima, it does not provide a secondary backup to protect against human errors by the controller in generating and issuing resolution clearances, or by the pilot in executing a clearance which was generated as a result of the conflict alert. Conflict Alert tells the controllers when a conflict situation starts and finishes. The controller, however, can suppress the alert, and no second warning is given if the situation fails to resolve itself. In short, there is no effective backup in the case of human error, such as clearance or altitude violations.

Conflict Alert will be effective in warning the controller of system errors. In most cases, this will result in successful resolution. In some percentage of the cases, however, where human errors occur, an automatic backup is needed. This need will be met by other elements of the aircraft separation assurance system.

Conflict Resolution is an advisory assistance to the controller in resolving an en route conflict alert situation. Development work is starting on the definition of the conflict resolution function for use in the en route center areas. As currently envisioned, Conflict Resolution would offer the controller a family of acceptable solutions, leaving the selection of the actual resolution for any given conflict up to the controller. It is envisioned that the Conflict Resolution advisories would be given to the controller at the time that the original Conflict Alert is displayed.

Automatic Traffic Advisory and Resolution Service

To address the high density airport problem (as well as other airspace regions), FAA is working on a system which uses ground-based computers tailored to the requirements of an individual airport. This system is called Automatic Traffic Advisory and Resolution Service (ATARS), illustrated in Figure 3.

ATARS makes use of ground computers which operate independently from the normal ATC computers and from the controllers themselves. This system employs an upgraded radar transponder system known as the Discrete Address Beacon System (DABS) being developed to serve a variety of future ATC system needs. This new DABS system is fully compatible and evolutionary with today's ATC system, and will incorporate an automatic communication channel -- a data link -- between the aircraft and these ground collision avoidance computers. This system will provide the needed information on transponder-equipped aircraft in all weather conditions, will include distance, altitude, direction and identity, and can be implemented without making obsolete the existing ATC safety systems.

Once the necessary equipment is installed on the ground, a user must buy a new airborne Discrete Address transponder and a display of his choice to make use of the service. This new transponder can replace his present ATC Beacon transponder at a modest cost increment, and will utilize the existing altitude encoder systems that are a necessary element of collision avoidance protection. Once an aircraft has the DABS transponder and ATARS data link equipment installed, it will receive immediate

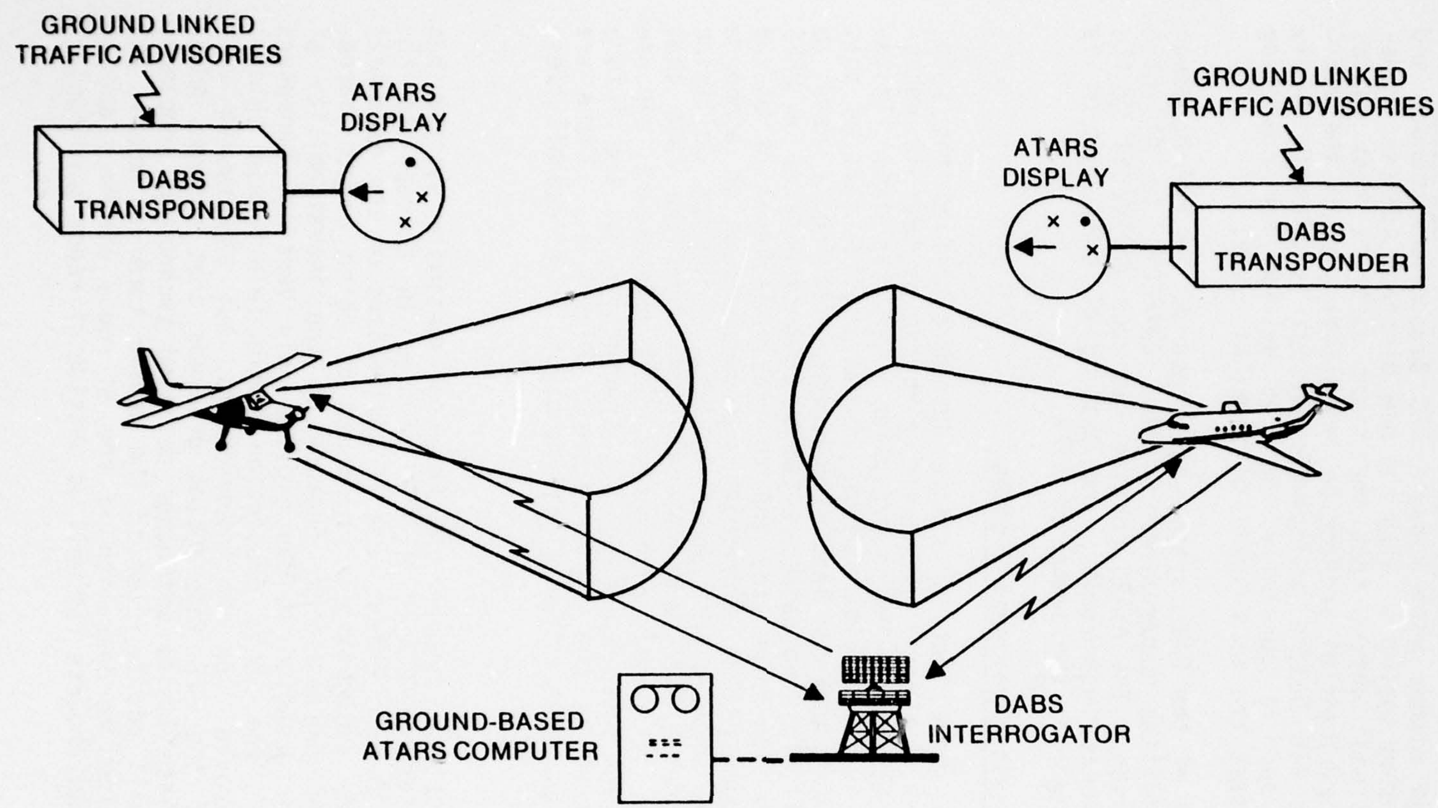


FIGURE 3
AUTOMATED TRAFFIC ADVISORY AND RESOLUTION SERVICE (ATARS)

protection within the ATARS service areas against <u>any other</u> aircraft equipped either with today's ATC Beacon transponder and altitude encoding system or with the new Discrete Address transponder. This will ensure that the first aircraft that equips will receive substantial protection immediately, since the altitude encoding ATC Beacon transponder system is already widely implemented, and is currently required by law for operating above 12,500 feet and in a number of terminal areas.

Final testing of the DABS system has begun at the FAA National Aviation Facilities Experimental Center (NAFEC), in Atlantic City, New Jersey. The ATARS portion has been delivered by the contractor, Texas Instruments, and testing of this portion is expected to begin in the summer of 1979.

Beacon-based Collision Avoidance Systems

It was noted above that no single system satisfies the total need, and that a mix of ground and airborne systems is necessary. The ATARS system is no exception -- it has known limitations. Even in its ultimate form, it can provide service only within Discrete Address Beacon coverage, leaving a need to develop a collision avoidance system that works outside of DABS coverage. To fill this gap, and to provide a level of backup within coverage, FAA is developing two versions of on airborne collision avoidance system known as BCAS -- Beacon Collision Avoidance System. The term "Beacon" stems from the fact that these systems, like their cooperative ATARS counterpart, can use the present altitude reporting ATC transponder or the future DABS transponder as the common element (Figure 4). There are two BCAS designs that differ significantly in their capabilities:

Active BCAS

The first and the simpler of these not-so-simple systems has been named "Active BCAS." It is similar in concept to the earlier ACAS systems except that it capitalizes on the essential protection and evolutionary advantages of being Beacon based. Like its ACAS predecessors, because of the inavailability of directional information it can provide only vertical maneuvers (climb/dive). The basic protection logic (electronic shield) has been improved over its predecessors, but the system will have many of the ATC interaction problems that plagued ACAS. Because of these limits and other detailed technology problems, the system will not be used in the denser terminal areas, but will be confined to operation in the en route airspace and in less dense environments (as well as outside of radar coverage).

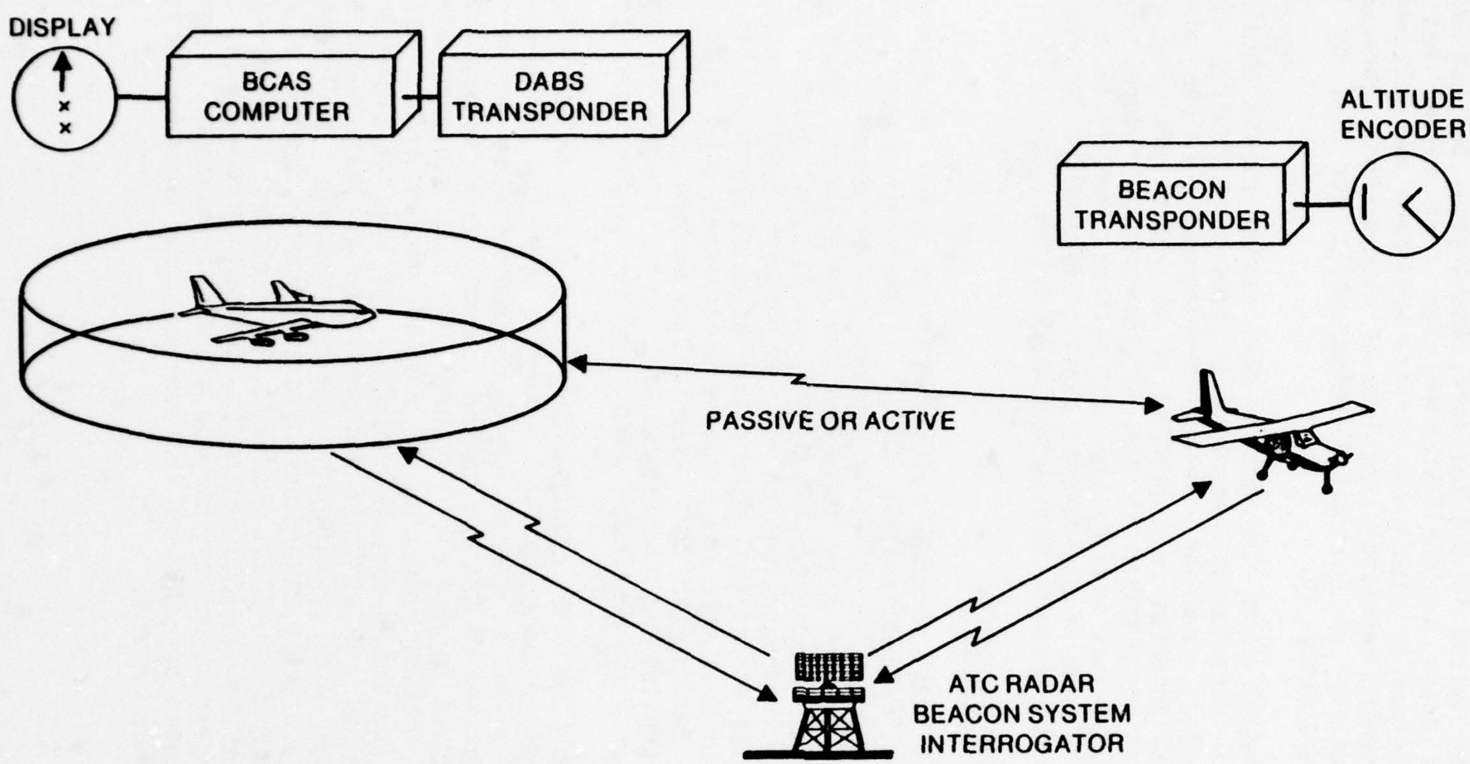


FIGURE 4
BEACON-BASED COLLISION AVOIDANCE SYSTEM (BCAS) CONCEPT

This system can in addition be made available earlier than any of its counterparts. Experimental models of this system have been flight tested in the New York, Washington, and Los Angeles areas. A draft National Standard for this system has been issued in order to enable the airline equipment manufacturers to begin designing marketable versions of this system. Three engineering models are currently being built for FAA by MIT's Lincoln Laboratory.

In its present form, the Active BCAS system cannot obtain the directional information necessary to provide a traffic display to the pilot. However, recent developments in the airborne directional antennas hold promise of at least partially eliminating this restriction in the not-too-distant future. FAA is investigating this possibility, and believes it will be possible to obtain a form of air-derived bearing information to provide a proximity display with this Active BCAS system.

Full Capability BCAS

The second type of BCAS system which is under development is called the "Full-capability BCAS." It provides a more complete service than Active BCAS, and makes use of recently developed techniques and new high speed computer technology. When operating in radar coverage, this system can "listen" passively without adding interrogations of its own in high density areas, and will provide directional information of much higher quality than is possible even with the airborne directional antenna mentioned earlier. Because of this important breakthrough, this system can also provide both horizontal and vertical maneuver commands in addition to an electronic display of surrounding aircraft.

Full-capability BCAS can operate in multiple modes of active and/or passive participation depending upon the radar coverage services available, the equipment on board the threat aircraft, and the density of traffic in the surrounding airspace. It provides protection to a Full-capability BCAS equipped aircraft from any intruder carrying an altitude reporting ATC Radar or Discrete Address Beacon transponder. It also provides traffic advisories on all aircraft equipped with at least Radar Beacon transponder, with or without altitude encoding. BCAS equipment includes a display, a processor, a transmitter capable of making interrogations on 1030 megahertz, a receiver capable of receiving replies on 1090 megahertz, top and bottom mounted directional antennas and a Discrete Address transponder. The frequencies used by BCAS are the same as those used by the ground surveillance systems.

In a purely passive mode, BCAS can listen to the replies that surrounding aircraft make in response to interrogations from several ground ATC Radar Beacon interrogators (of which at least one is equipped with an azimuth reference) and can infer the position of own aircraft relative to other aircraft. When operating within the coverage of only a single ATC Radar Beacon interrogator, BCAS can augment its surveillance by making its own active interrogations of the surrounding aircraft and of a fixed transponder placed on the ground at the radar interrogator location. When operating within coverage of a single Discrete Address Beacon interrogator, BCAS can infer the positions of surrounding aircraft by listening passively to their replies to DABS interrogations, and by listening to certain information describing the current pointing direction of the Discrete Address ground antenna as transmitted by the DABS sensor. BCAS can also operate (albeit with somewhat more limited information) outside the coverage of any Beacon radars by operating in a purely active mode. In this mode, BCAS makes its own interrogations and listens to the replies of surrounding aircraft carrying DABS or Radar Beacon transponders to those interrogations. Threat direction (PWI) advisories are provided by employing the directional antennas in the active mode.

Like ATARS, BCAS is designed to provide traffic advisories and to issue maneuver advisories in the last moments before collision. In each of its operating modes, BCAS exchanges information with another BCAS unit at the time of detecting a conflict in order to coordinate the advisories being displayed. BCAS generates and displays traffic advisory information on threats equipped with DABS or Radar Beacon transponders, with or without altitude reporting capability. BCAS decision thresholds for advisories are comparable to those used by ATARS. BCAS is currently in the experimental stage and would not be implemented in its full capability form for several years.

The Full-capability BCAS described above provides service in all airspace well into the 1990 time period. It will provide backup protection to equipped users in all airspace (particularly airspace with high aircraft densities) until ATARS is implemented.

Both the full capability and limited capability systems are interfaced with ATARS through the DABS data link. BCAS resolution advisories are suppressed when the aircraft operates in an ATARS service area.

The technology for Full-capability BCAS is still new. Basic experiments are now being conducted at FAA's National Aviation

Facilities Experimental Center. FAA is in the process of contracting with avionics equipment manufacturers for design studies leading to the construction of several models of this system for test and evaluation.

Time Frame for the Elements of the Aircraft Separation Assurance Effort

As discussed above, no single device can offer a complete solution to the problem, thus a mix will be necessary. The ATARS system is needed to deal effectively with the high density areas typical of the major airport areas. The Active BCAS or the Full-capability BCAS system can provide protection outside of ground radar coverage and in less-dense regions (including portions of uncontrolled airspace) where the ATARS system would not be implemented. In addition the Full-capability BCAS can backup ATARS in high density airspace, and will provide the bridge until DABS/ATARS is fully implemented.

The time frames projected for the availability of the various systems also differ. The ATARS and the Active BCAS systems are furthest along in the development process. Testing of DABS and ATARS will begin early in 1979 at NAFEC. Earlier tests of this system were conducted in the Boston area in 1975-76. Deployment of the ground elements are expected to begin in late 1983. Experimental tests of the Active BCAS have been conducted and the draft National Standard has been issued this month.

The Full-capability BCAS system is in an earlier stage of development than the other two systems because its technology is much newer and because it is more complex. This system will take several more years of development to perfect. Sufficient development data to support a draft National Standard will be available in February 1982.

Dependence on ATC Transponders

The aircraft separation assurance program depends on widespread use of ATC Beacon transponders with altitude-encoding capabilities. It presumes a timely transition to Discrete Address transponders, especially for new and replacement transponder purchases. For this reason the program calls for altitude reporting Beacon transponders in all radar terminal areas (TCA/TRSA) by July 1981, and for DABS transponders in new installations after July 1982.

Prospective Effectiveness of the FAA Program

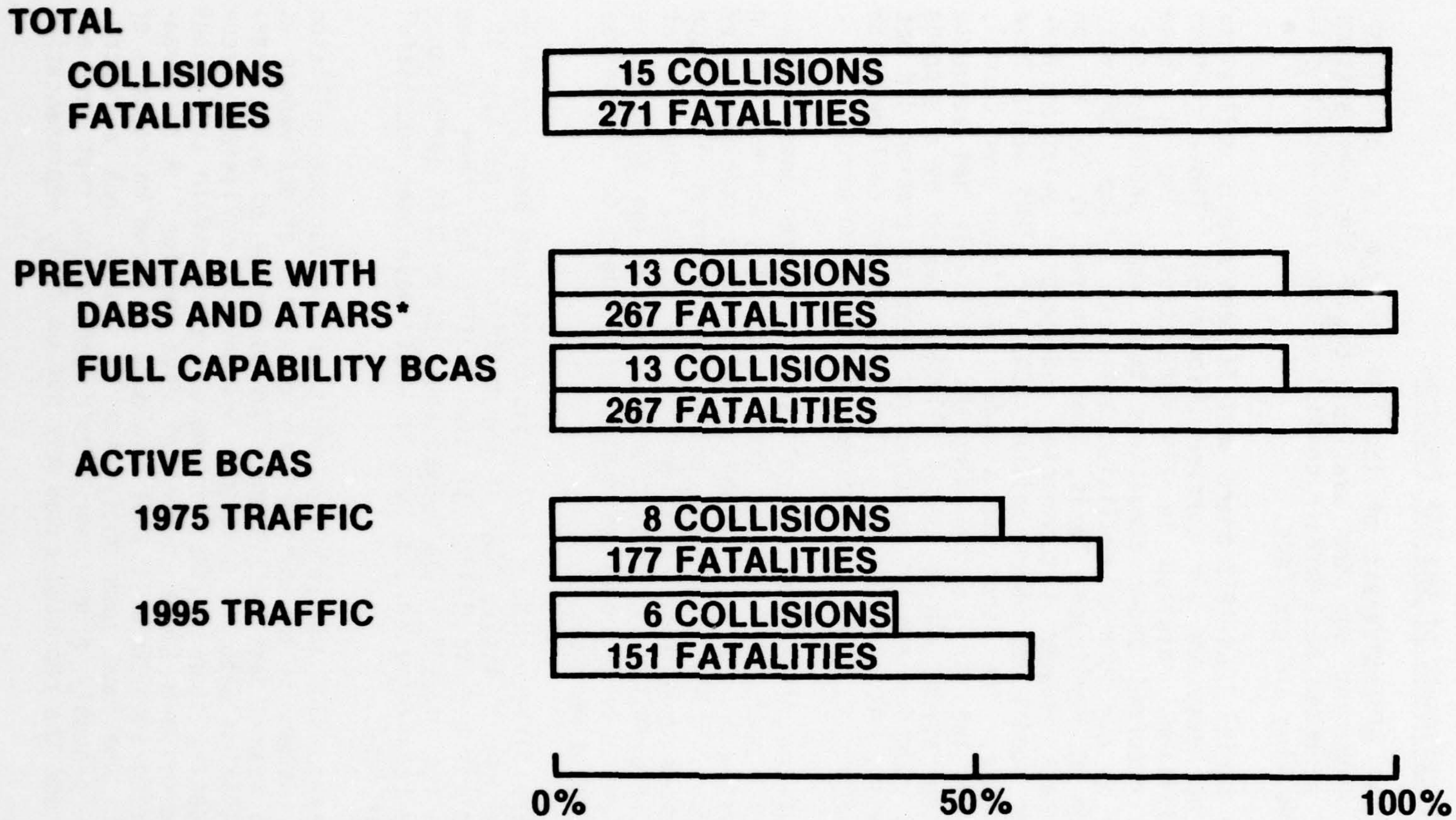
The potential effectiveness of the FAA program can be illustrated by examining how the availability of the new systems might have affected past midair collisions and near-midair collisions involving air carriers.

During the period 1964-1972 there were fifteen midair collisions involving at least one air carrier (Figure 5). Those fifteen midair collisions resulted in 271 fatalities. Two of those collisions occurred under conditions that were probably not resolvable by any form of collision avoidance system. One was a collision at Harlingen, Texas, that occurred at 200 ft. on final approach between a commercial and general aviation aircraft under conditions where neither BCAS nor ATARS would have been effective. The other was a midair collision over Carmel, NY, in which two air carrier aircraft initially had adequate altitude separation, but a visual illusion caused by a sloping cloud deck caused one pilot to conclude that separation did not in fact exist. As a result he pulled up into and collided with the other aircraft. This was a clear case of human error.

Thirteen of the fifteen midair collisions occurred under conditions where either the Automatic Traffic Advisory and Resolution Service System or the Full-capability BCAS might have prevented the collision. All of these collisions occurred in Beacon ground system coverage. Considering the risks, the use of Full-capability BCAS, or of DABS/ATARS in coverage plus active BCAS for use outside coverage areas, are judged to be equivalently valuable services.

Eight of the fifteen midair collisions might have been prevented through the use of Active BCAS if the traffic level had been at levels experienced in 1975. If the traffic had been at the level expected in 1995 it is judged that Active BCAS performance would have been degraded and that it would have been successful in only six cases.

Another way to view the relative merit of the various collision avoidance systems is to examine their potential effectiveness at preventing near-midair collisions. An advantage of using near-midair collision data is that the near-midair collisions occur more frequently than do the fortunately rare midair collisions and thus provide a larger number of data samples. A disadvantage of using such data is that the data is based on reports of individuals who have some motivation to submit such a report. There are probably other near-midair collisions that are not reported, and the reported cases may not be fully representative



*ALL AIR CARRIER COLLISIONS OCCURRED WITHIN RADAR COVERAGE—SAME PERFORMANCE HOLDS WITH OR WITHOUT ACTIVE BCAS

FIGURE 5
ATARS/BCAS PERFORMANCE ASSESSMENT 1964-1972—MIDAIR COLLISIONS INVOLVING AT LEAST ONE AIR CARRIER

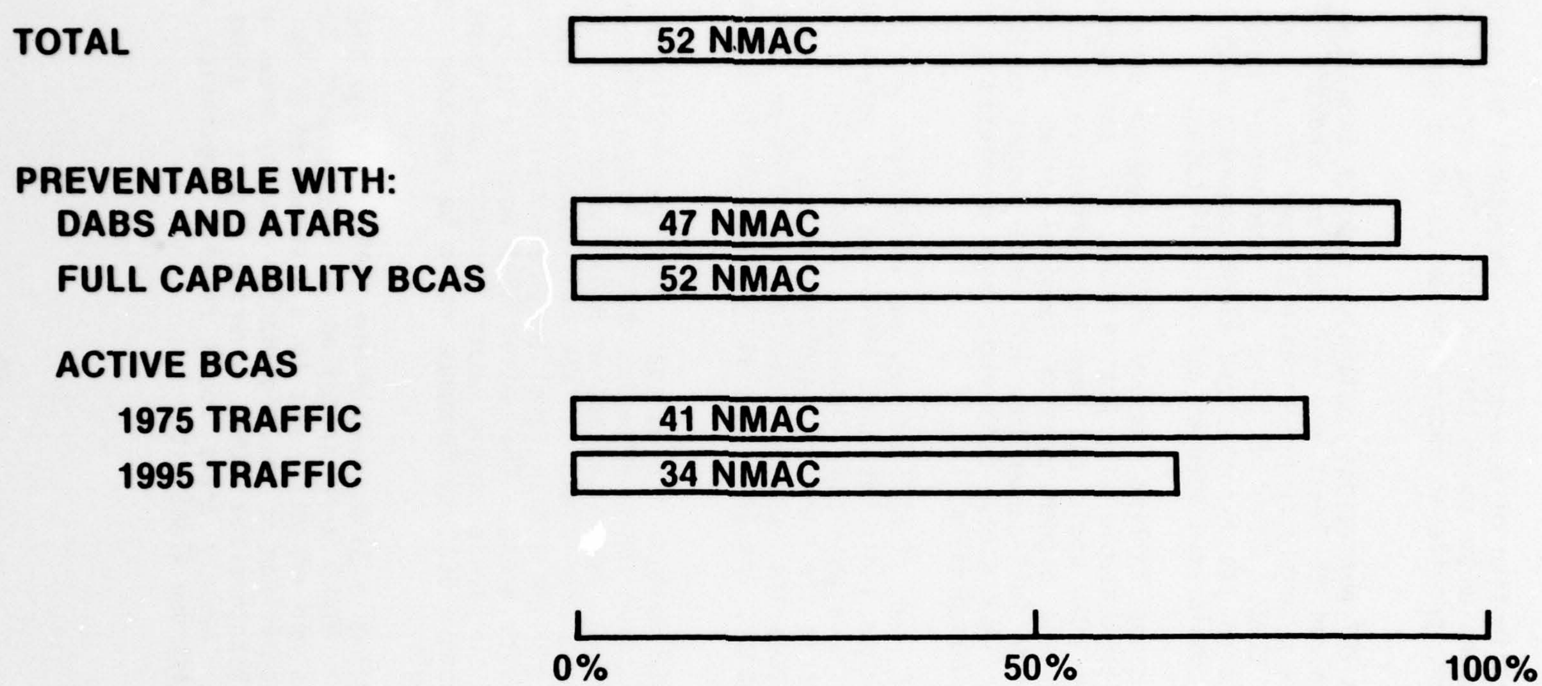


FIGURE 6
ATARS/BCAS PERFORMANCE ASSESSMENTS 1964-1972—NEAR-MIDAIR COLLISIONS INVOLVING AT LEAST ONE AIR CARRIER

of the distribution of near-midairs throughout the system, or of the conditions under which they occur. The near-midair reports do, however, provide an indication as to where improvements are possible.

Out of the 227 near-midair collision reports tabulated in Figure 1, 52 involved at least one air carrier aircraft (Figure 6). All 52 were potentially preventable through the use of the Full-capability BCAS. Five of those 52 near-midair collisions occurred outside the hypothesized ATARS coverage with the result that ATARS would have been effective in 47 cases.

The five cases falling outside ATARS coverage were likely to have been preventable with Active BCAS. It was judged however that active BCAS would not have been effective in 11 cases occurring in the higher density terminal areas -- cases where ATARS and the full-capability BCAS were judged as likely to be effective. Thus Active BCAS might have prevented a total of 41 of the 52 near-midairs.

This brief and simplified review of midair and near-midair collision data indicates that ATARS has the potential of providing for a significant increase in collision avoidance protection within the airspace receiving ATARS services. The data also indicates the need for additional protection outside of the ATARS airspace, and FAA believes active BCAS is the most suitable answer.

Even in 1990 most of the airspace over the contiguous 48 states will lie outside the high/medium density areas (Figure 7). This is the airspace where an active BCAS system would be the most effective. Either ATARS or the Full-capability BCAS would be needed to provide a high level service within the circled high/medium density areas. The active BCAS would also provide some protection in these areas under certain conditions but, in general, active BCAS performance would be degraded, and likely not available.

Figure 8 shows a plan view of the ATARS coverage that would be realized if ATARS were installed at 162 Airport Surveillance Radar sites and effective out to a distance of 50 nmi from each site. A comparison of the high/medium density areas of Figure 7 with the hypothesized ATARS coverage Figure 8 shows that all high/medium density areas would receive separation advisories from at least one ATARS site.

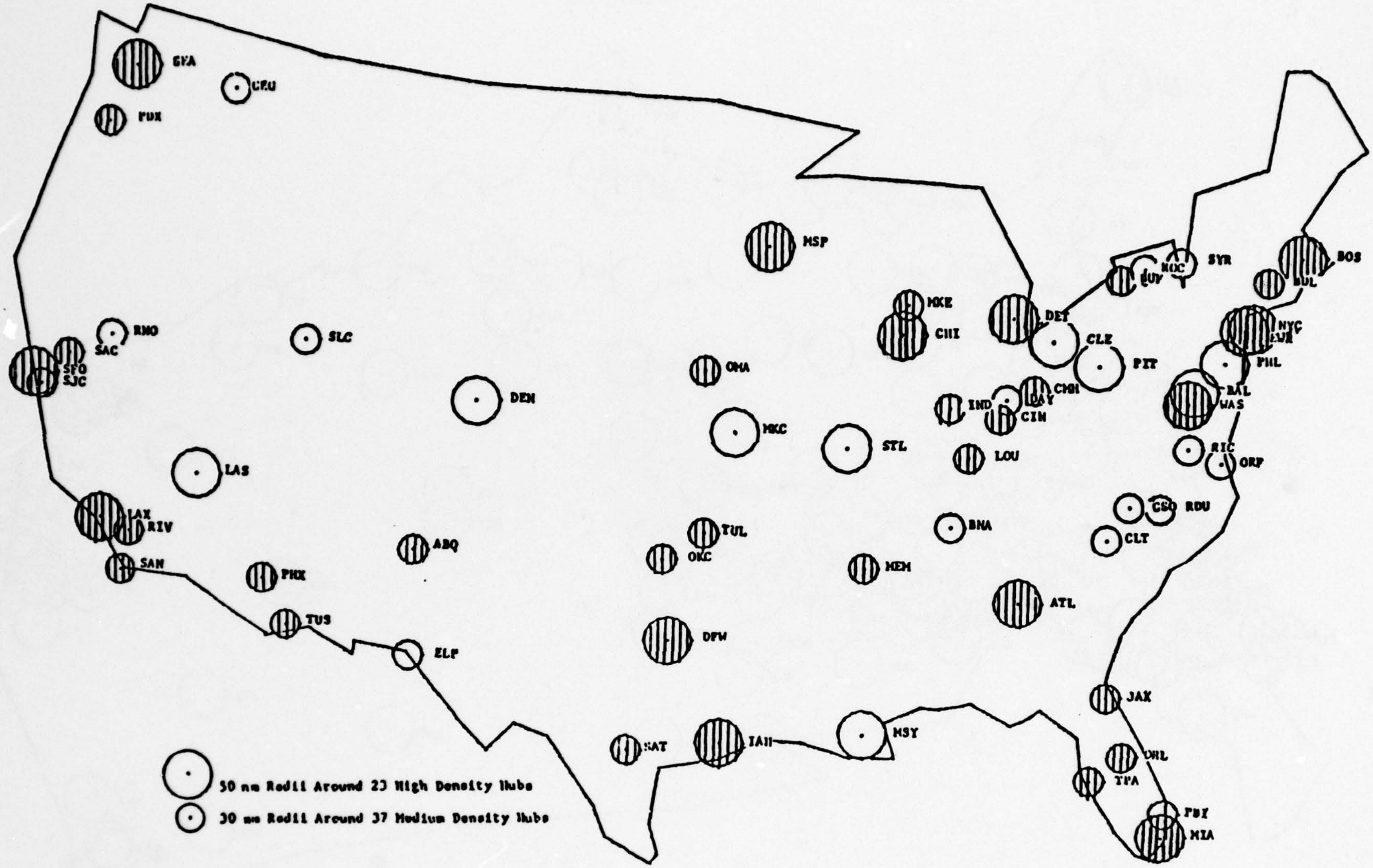


FIGURE 7
1990 HIGH/MEDIUM TRAFFIC DENSITY AREAS

ATARS AT 162 AIRPORT SURVEILLANCE RADAR SITES.
50 nmi RADIUS OF EFFECTIVENESS.

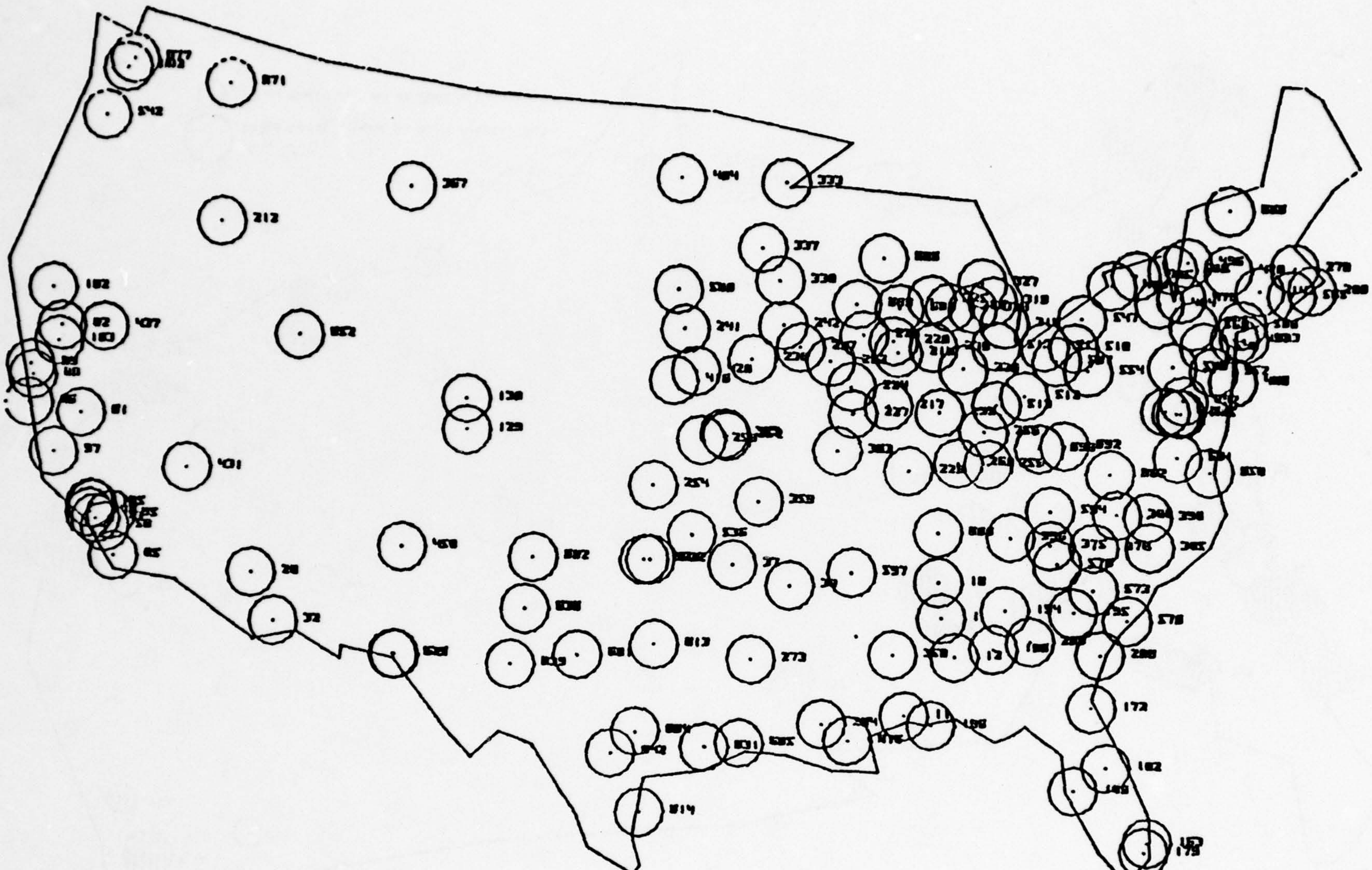


FIGURE 8
DABS COVERAGE SUPPORTING ATARS

Developments for Lower Activity Airports

With the provision of ATARS, and the carriage of BCAS by air carriers and some general aviation -- especially the commuter carriers -- the major sources of public transportation collisions and fatalities within the controlled system and at the boundary between controlled and uncontrolled airspace are addressed. One remaining portion of the program is directed to the general aviation operations at small uncontrolled airfields which do not now have towers today but support a large enough number of operations to cause concern about the risk of collisions and consideration of providing a VFR tower with all of its limitations. A new capability now under development, the Automated Terminal Service (Figure 9), is designed to reduce the risk of collision at such airports and to provide other services as well. Through the use of the ATC Radar Beacon system with altitude encoding, and an automated voice-response system, the Automated Terminal Service provides traffic advisories to the aircraft in the pattern, management of the traffic pattern itself in terms of sequencing, as well as the normal weather and runway advisory services provided by the Automated Terminal Information Service at larger airports. This system may provide a more cost effective solution than the installation and operation of a tower.

The additional provision of a Discrete Address interrogator with its data link at these facilities would support the addition of an ATARS type service. Such a service would provide both improved collision protection in and around the airport, and additional sources of low altitude coverage of the Automated Traffic Advisory and Resolution Service. The avaiability of DABS Data Link and ATARS at these low density fields would provide a system-compatible approach to addressing the collision risk outside controlled airspace.

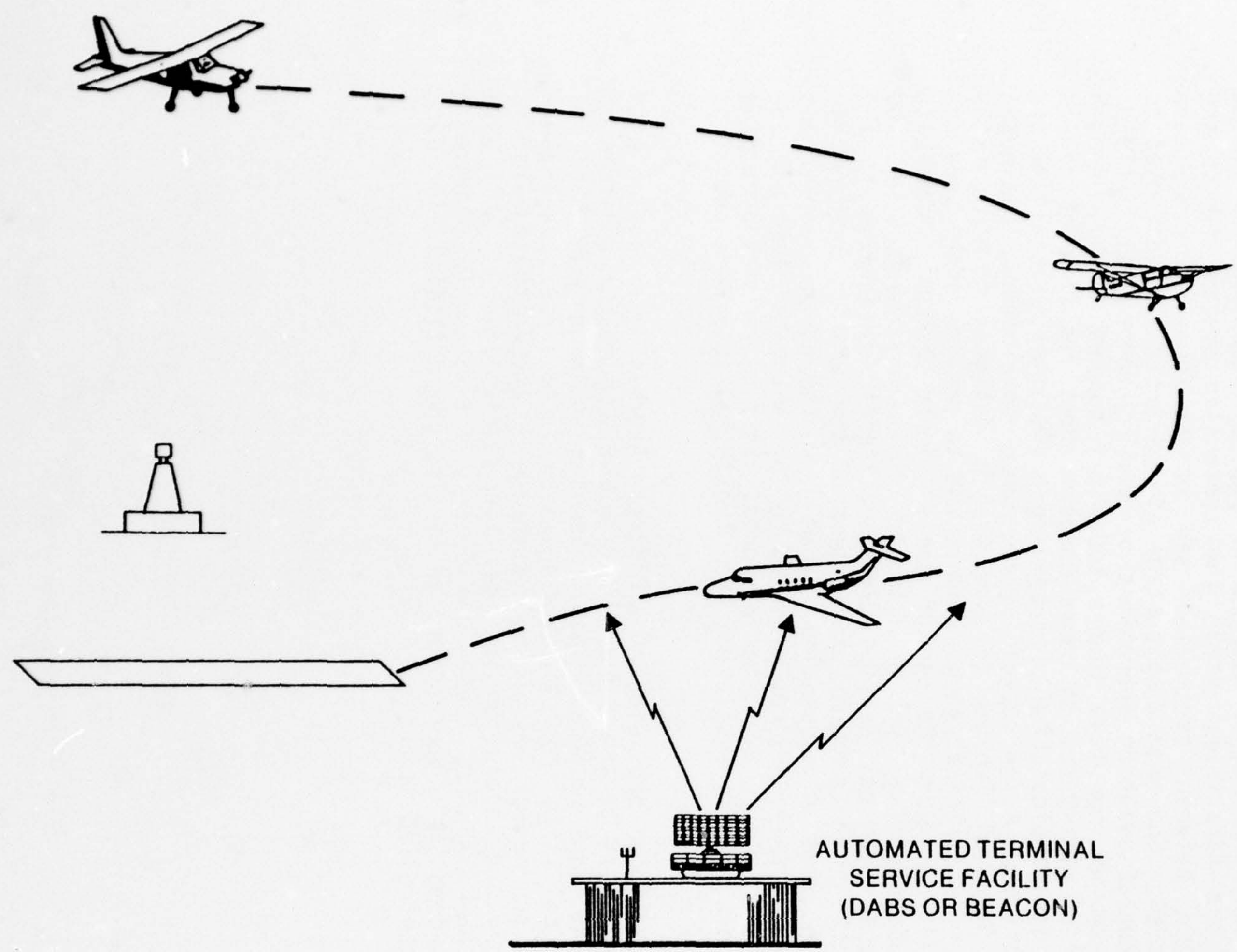


FIGURE 9
AUTOMATED TERMINAL SERVICE (ATS) CONCEPT FOR SMALL GENERAL AVIATION AIRPORTS

Summary

FAA's aircraft separation assurance program offers compatible collision protection both within and outside the controlled system.

In the controlled airspace where most all air carriers and many commuters and instrument-equipped general aviation aircraft routinely fly, the primary source of separation assurance will continue to be the air traffic control system backed by the Conflict Alert service.

To provide a backup, three interrelated elements were announced in the Administrator's plan of 27 December 1978:

- o Within coverage, the Discrete Address Beacon System and the Automated Traffic Advisory and Resolution Service will provide the primary backup to the air traffic controller in both medium and high density areas as well as in the en route system at high altitudes.

- o Where coverage is limited or traffic is light, the Beacon Collision Avoidance System, either Active or Full-capability BCAS, as chosen by the operator, will provide protection against uncontrolled transponder-equipped aircraft operating in and around the fringes of the controlled system.

- o Clearance verification via DABS Data Link which will result in reductions in misunderstanding between pilots and controllers as to the parameters of each air traffic clearance. This in itself should assist in reducing system errors and associated near-midair collisions.

These efforts depend on widespread carriage of either Discrete Address or conventional Beacon transponders with altitude encoding in order to provide the maximum protection to the users.

Outside controlled airspace, in regions in which primarily commuter, air taxi, and the small general aviation aircraft operate, FAA expects to provide three levels of service for collision protection:

- o Where low altitude radar coverage exits from the DABS sites of the controlled system, or where it can be extended through provision of DABS at the Automated Terminal Service locations, a primary source of collision

avoidance protection, that is, the Automated Traffic Advisory and Resolution Service, will be available.

- At small general aviation airports that might in the future qualify for a Control tower because of traffic densities or collision risk, improved services through the provision of the Automated Terminal Service will be available.

- Finally, at the smaller, lower density fields that make up the bulk of 12,500 airports in this country, FAA will continue to rely on the use of basic air traffic procedures plus the communications provided by UNICOM service. FAA expects that in order to provide effective UNICOM service to sufficient airports, discrete airport frequencies will have to be assigned, and this effort is underway.

APPENDIX A

AIRBORNE COLLISION AVOIDANCE SYSTEMS

The first attempt at developing a Collision Avoidance System in an independent airborne system was spearheaded by the McDonnell-Douglas Corporation in the early 1960's, working primarily with the airlines. The system they developed used technology that was advanced for the time, and was based upon the use of expensive and delicate atomic clocks. The system did not make use of directional information, and, consequently, could provide only vertical avoidance maneuvers only -- climb, descend. Limited flight tests of this system were conducted by the Martin-Marietta Corporation in 1968 and 1969. To complement this hardware development, the airlines developed and published a set of computer logic defining the desired alarm parameters, warning times, etc., which matched the capabilities of this device.

While the McDonnell-Douglas system, called "EROS," was being perfected, two other companies entered the collision avoidance field; RCA began developing an airborne system which they called "SECANT," and Minneapolis-Honeywell undertook the development of an airborne system called "AVOIDS." While different in the technology used, the RCA and Honeywell systems were almost identical in concept to the McDonnell-Douglas approach. None of these systems had directional information available and all were limited to vertical escape maneuvers.

The RCA and Honeywell proposals used then newly-feasible technology and were potentially lower in cost than the McDonnell device. Within the aviation industry, these three systems collectively became known as "ACAS" systems -- Airborne Collision Avoidance Systems.

In 1971, the FAA undertook a comprehensive program to complete the development and to evaluate all three of these systems. FAA awarded contracts to all three of these manufacturers to obtain operating systems for flight test. A series of simulations was conducted at FAA's National Aviation Facilities Experimental Center (NAFEC) in Atlantic City, New Jersey, to assess how the systems would perform under varying traffic and operational conditions. A joint flight test program was established with the Department of Defense in which live flight tests were conducted at NAFEC and at the Naval Air Development Center in Warminster, Pennsylvania. This program of evaluation was completed in 1975.

The fundamental conclusions of this evaluation were:

- All of these systems were limited to use <u>outside</u> the dense terminal areas since they produced undesirable ATC interaction or false alarm problems when operating in the dense terminal regimes.

- All of these systems lacked an important evolutionary capability in that they could not be introduced gradually and build upon the current ATC system base. These systems were fully cooperative and required that new equipment be installed almost simultaneously in most aircraft to achieve protection. The first person who bought the system received no protection until others installed the device.

- These systems would not provide protection against foreign aircraft operating in U.S. airspace since, as a practical matter, such action would require worldwide standardization of these systems and adoption by the International Civil Aviation Organization -- an unlikely prospect since there was little international interest in collision avoidance systems.